CONTROL RECTIFIER FOR VARIABLE SPEED SINGLE PHASE DC MOTOR

MOHD HELMI BIN SAMTA

This thesis is submitted as partial fulfillment of the
requirements for the award of the
Bachelor Degree of Electrical Engineering (Power Systems)

Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

MAY 2008

Signature : ______________________________

Author : MOHD HELMI BIN SAMTA

Date : 8 MAY 2008

To my beloved mother, father, and brothers

“I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)”

Signature : ____

Name : MR.MUHAMAD ZAHIM B SUJOD

Date : 8 MAY 2008

ACKNOWLEDGEMENT

First and foremost, I would like to thank God the Almighty for his bless towards myself. Without his blessing I might not be able to complete my final year project entitled “Control Rectifier for Variable Speed Single DC Motor”. I able to complete this research project in time as a partial fulfillment of the requirement of the degree of Bachelor Electrical Engineering (Power System).

Secondly, I would also like to take this opportunity to thank all the people who had assisted me directly and indirectly in completing the project. My first gratitude goes to Mr. Muhamad Zahim bin Sujod, my one and only supervisor for the project whom had given all the support, advice and guidance I might need. He had been guiding me from the very start of the project until the final touch of the thesis write up. With his helps, I had learned many things regarding the project, as well as extra knowledge that I believe I would not have this sort of opportunity elsewhere. The project would obviously not be successful without him. A million thanks to Mr. Muhamad Zahim bin Sujod.

Very special thanks also to other friends who had guided and helped me a lot with the project. Not to forget, I would also wish to thank all of my lecturers who had given their full co-operation. They had never hesitated to share knowledge and opinions in ensuring the project be completed successfully.

Last but not least, I would like to thank my beloved parents who had given me a lot of moral support while I was struggling with this project.

ABSTRACT

An electric power can be converted from one form to another form by using power electronics devices. The function of power electronics circuits by using semiconductor devices as switch is modifying or controlling a voltage. The goal of power electronics circuits are to convert electrical energy from one form to another, from source to load with highest efficiency, high availability and high reliability with the lowest cost, smallest size and weight. The term rectification refers to the power circuit whose function is to alter the ac characteristic of the line electric power to produce a “rectified”ac power at the load side that contain the dc value. In this project task, the rectifier circuit should be possible to produce a variable average voltage by controlling the delay. The single phase 240 V_{rms} AC source is stepped down to 12 V_{rms} by using step-down power transformer. A versatile method of controlling the output of a full-wave rectifier is to substitute controlled switches such as SCRs for the diodes. The output is controlled by adjusting the delay angle of each SCR, resulting in an output voltage or output current which is variable over a limited range with programmed the microcontroller (PIC16F84A).

ABSTRAK

Kuasa eletrik boleh diubah daripada satu bentuk ke bentuk yang lain dengan menggunakan litar peranti kuasa elektronik.Fungsi litar elektronik berkuasa dengan menggunakan peranti semiconductor sebagai suis untuk mengawal dan mengubah arus voltan.Matlamat litar elektronik berkuasa adalah untuk mengubah kuasa elektrik kepada bentuk yang lain, daripada sumber kuasa kepada beban dengan tahap kecekapan yang tertinggi, perihal boleh didapati yang tertinggi ,perihal yang dapat dipercayai tertinggi dengan kos yang paling murah ,saiz dan berat yang paling kecil.Istilah rektifikasi merujuk kepada litar kuasa yang berfungsi untuk mengubah ciri ac dalam “line” kuasa elektrik untuk menghasilkan “rectified” ac pada beban yang mengandungi nilai dc .Dalam tugasan projek ini, litar “rectifier” sepatutnya akan menghasilkan nilai purata arus voltan yang berubah dengan mengawal kelambatan . Sumber kuasa satu fasa 240 Vrms, diturunkan kepada 12 Vrms dengan menggunakan “ step-down power transformer”.Berbagai kaedah mengawal keluaran “full-wave rectifier” dengan menggantikan diod kepada suis yang boleh dikawal iaitu SCR’s.Keluaran dikawal dengan mengubah nilai “delay angle”setiap SCR’s ,yang mana nilai arus voltan atau nilai arus adalah berubah pada lingkungan yang terhad dengan memprogram mikropengawal (PIC16F84A).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	-	Alternate Current
DC	-	Direct Current
SCR	-	Silicon Control Rectifier
PIC	-	Programmable Intelligent Computer
IC	-	Integrated Circuit
LCD	-	Liquid Crystal Display
RCT	-	Reverse Conducting Thyristor
DIAC	-	Diode for Alternating Current
SIDAC	-	Silicon Diode for Alternating Current
TRIAC	-	Triode for Alternating Current
GTO	-	Gate Turn-Off Thyristor
IGCT	-	Integrated Gate Commutated Thyristor
MCT	-	MOSFET Controlled Thyristor
SITh	-	Static Induction Thyristor
FCTh	-	Field Controlled Thyristor
BJT	-	Bipolar Junction Transistor

LIST OF SYMBOLS

α	-	Delay Angle
μs	-	mikroseconds
kV	-	kilovolt
kHz	-	kilohertz
V	-	Volts
MW	-	Megawatt
kW	-	kilowatt
Vrms	-	Volts Root Mean Square
f	-	Frequency
°	-	Degree
ms	-	miliseconds
mV	-	milivolts
η	-	Efficiency
MHz	-	Megahertz

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

The modern era of power electronics began in 1958 ,when the General Electric Company introduced a commercial thyristor ,two years after it was invented by Bell Telephone Laboratory. Soon all industrial applications that were based on mercury-arc rectifiers and power magnetic amplifiers were replaced by silicon-controlled rectifiers(SCRs).In less than 20 years after commercial SCRs were introduced significant improvements in semiconductor fabrication technology and physical operation were made ,and many different types of power semiconductor devices appeared.

The growth in power electronics was made possible with the microelectronic revolution of the 1970s and 1980s ,in which the low power IC control chips provided the brain and the intelligence to control the high – power semiconductor devices .Moreover the introduction of microprocessors made it possible to apply modern control theory to power electronics. In the last 20 years ,the growth in power electronics application has been remarkable because of this introduction of very fast and high-power switching devices, coupled with the utilization of state-of –the –art control algorithms.

An electric power can be converted from one form to another form by using power electronics devices. The function of power electronics circuits by using semiconductor devices as switch is modifying or controlling a voltage. The goal of power electronics circuits are to convert electrical energy from one form to another, from source to load with highest efficiency, high availability and high reliability with the lowest cost, smallest size and weight.

There are four conversion circuits that are used in the majority of today's power electronics circuits. Firstly are ac-to-ac ,secondly is ac-to-dc ,thirdly is dc-to-ac and the last is dc-to-dc.In terms of functional description ,modern power electronics system perform one or more of the following conversion functions.

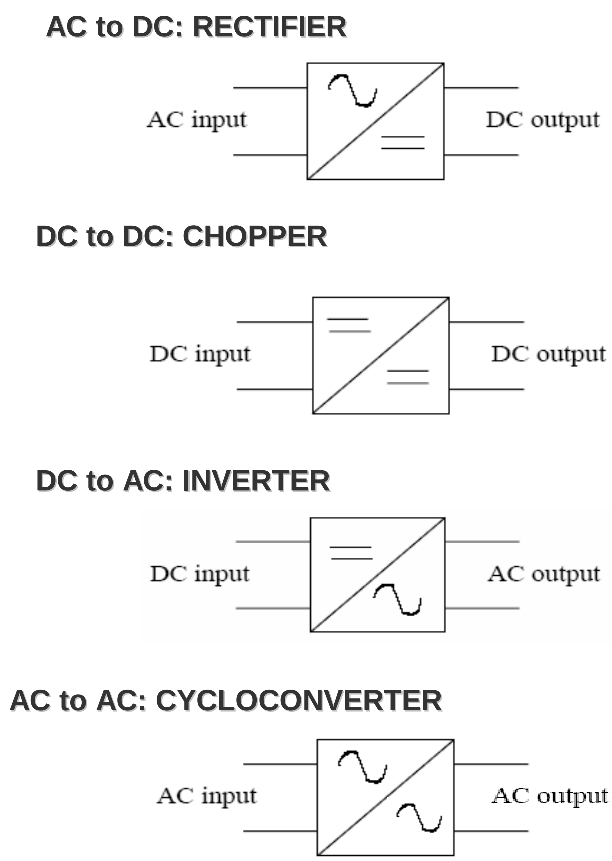

Figure 1.1 Four Types of Conversion

1.2 Background

Power electronic converters can be found wherever there is a need to modify the electrical energy form (i.e modify its voltage, current or frequency). Therefore, their power range from some milliwatts (as in a mobile phone) to hundreds of megawatts (e.g in a HVDC transmission system). With "classical" electronics, electrical currents and voltage are used to carry information, whereas with power electronics, they carry power. Therefore the main metric of power electronics becomes the efficiency.

The first very high power electronic devices were mercury arc valves. In modern systems the conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors. In contrast to electronic systems concerned with transmission and processing of signals and data, in power electronics substantial amounts of electrical energy are processed. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices, e.g., television sets, personal computers, battery chargers, etc. The power range is typically from tens of watts to several hundred watts. In industry the most common application is the variable speed drive (VSD) that is used to control an induction motor. The power range of VSDs start from a few hundred watts and end at tens of megawatts.

Most power electronics systems consist of two major modules as shown in Figure 1.2 which are power electronics processor that handles power transfer from input to output and controller that tells the power processor of what to do by taking the measurement that happens at output and compared to input.

For example, if we have an AC power input, but need DC input for charging the laptop, thus, we need something to convert that input to another form. Power semiconductor devices are characterized by having the two states which “on” and “off” or being either a short circuit or an open circuit. Advance in semiconductor switching capability combined with the desire to improve the efficiency and performance of electrical devices are making power electronics a fast-growing area in electrical engineering [1]. Thereby using switching devices for many applications are desirable because of the relatively small power loss in the device.

Applications of power electronics range from high-power conversion equipment, for examples DC transmission to everyday appliances such as power supplies for notebook computers. Conversion of AC to DC produces a DC output from an AC input is shown in Figure 1.1. This AC-DC converter is also specifically classified as a rectifier. Average power is transferred from an ac source to a dc load [1]. An AC-DC converter enables integrated circuits to operate from a 50/60 Hz AC line voltage by converting the AC signal to a DC signal of the appropriate or suitable voltage. Therefore, this project is assigned as to design and build a single phase controlled AC to DC converter. Most electronic devices are sold in the stories that required fixed AC to DC conversion.

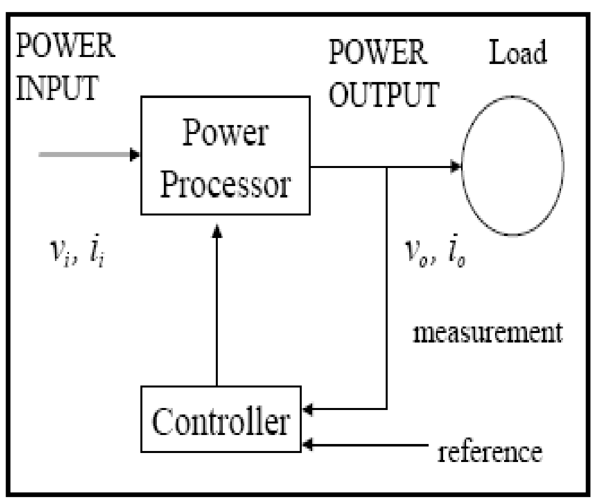

Figure 1.2 Power Processor & Controller

1.3 Objectives

The objective or the purpose of this project is the important part of getting started because it will drive to the outcomes of this project.Basiclly there are two main purpose which are ,firstly to explore and learn the operation of PIC16F84A to control thyristor circuit and secondly to build and test the circuit to control variable speed DC motor. Besides the two main objectives there are also others outcomes that need to be reach at the end of this project such as to produce DC voltage or current with low ripple and to produce the output close to the theoretical value.

1.4 Scopes

This project concentrates on a development of a circuit and hardware to get dc output using SCR and PIC16F84A as main component of the project. Besides the scopes is to program a microcontroller to control delay angle alfa and it produced variable outputs (speed).

To develop the whole project, it consists of three methods which are the concept of switching , the electrical structure, and the software programming.

After designing and building completely the rectifier circuit, the driver circuit should be able to control the delay angle α, that can be adjusted by using microcontroller. It will involve the programming development to control the ON state of the power switch and adjust the phase angle. Here, the trigger angle of SCRs will be programmed in certain time sequence to ensure the input voltage goes from low to full voltage

1.4 Problem Statement

A rectifier is an electronic circuit that converts bidirectional voltage (AC voltage) to unidirectional voltage (DC voltage) by using power diodes or by controlling the firing angle of thyristor/controllable switches. Rectifier usually can be divided into two types that are uncontrolled and phase-controlled. Each type can have either single-phase or three-phase. A diode is the simplest electronics switch which it is uncontrolled that the on and off states can be determined by the power supply in the circuit itself. AC to DC converter is mostly used in industries and also in domestic equipment. But many rectifiers in the market only produce fixed output so the applications of the rectifiers are limited for certain equipment only. So, the DC level of the output and the power transferred to the load are fixed when the source and load parameters are established.

Hence, to overcome this problem there is a way to control the output voltage of the rectifier. Basically, the single phase rectifier is designed using the thyristors or more specifically are called Silicon Control Rectifier (SCR) which connected in full-wave rectifier. A thyristor is four layers (pnpn) semiconductor devices that act as switches, rectifiers or voltage regulators. Thyristors are electronic switches used in power electronics circuits where control of switch turn-on is required [1]. Thus, the output voltage can be variable from the range of zero voltage to full voltage by controlling the delay angle of the SCR.

1.5 Thesis Outline

There are all five chapters being structures in this thesis and every chapter will elaborate in detail about this project. For the first chapter, an overview about this project, single phase controlled rectifier is discussed including the objectives and scopes of the project as a guide to develop the single phase controlled rectifier.

Chapter 2 will explain and discuss on the literature review of the single phase controlled rectifier. It also focuses on general introduction of the AC to DC converter with the complete information about this converter. It gives a brief review about the types of the rectifiers: uncontrolled and controlled single phase and three phase converters used as rectifiers. In this chapter also discuss about the type of thyristor and the characteristic of each type.

Chapter 3 discusses the methodologies of the single phase controlled rectifier that has been applied in completing this project. In this chapter, it consists of block diagram and flow chart which are explained about the process of implementation and how the AC voltage converts to DC voltage then connected to the load such as DC motor. It is also discusses briefly how the output voltage can be varied.

Chapter 4 is discussing and displaying all the results obtained and the limitation of the project. All discussions are concentrated on the result and the overall performance of the single phase controlled rectifier.

Chapter 5 in overall will discuss on the conclusion and summary of the development of the single phase controlled rectifier completed project. In this chapter also discusses on the problems and recommendation for this project development or modification.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review about this project have been made from various sources like journals, books, articles and others. From the literature review ,the input that have been collected is useful for better understanding of this project. It is because for nearly a century, rectifier circuits have been the most common power electronics circuits used to convert AC to DC. The AC-DC converter produces a DC output from an AC input while the average power transferred from an AC source to a DC load. This converter usually also called as a rectifier. The word rectification is used not because these circuits produce DC but rather because the current flows in one direction. Generally, there are two types of AC-DC converters which are uncontrolled and controlled. The input of these converters can be single phase or multi-phase (3 phase).

2.2 Uncontrolled Single Phase Rectifier

This type of rectifier consists of half-wave rectification and full-wave rectification. Uncontrolled rectifiers make use of diodes. Diodes are two-terminal semiconductor devices that allow flow of current in only one direction. The two terminals of a diode are known as the anode and the cathode. The designs are cheap and popular in the industrial applications. In some of these rectifiers, the AC source from the electric utility is directly rectified without using of an expensive and bulky transformer. In some applications, the DC voltage from the rectifier is connected to a DC bus for distribution to several different circuit systems, subsystems and other converters as loads [10]. In other applications, the rectifiers also supply power to inductive-resistive (motors) and capacitive-resistive (power supplies) loads.

2.2.1 Single Phase Half-Wave Rectifiers

The simplest of the rectifier circuit is a single phase half-wave rectifier consists of a single diode as shown in Figure 2.1. A diode is the simplest electronic switch. It is uncontrolled in that the on and off conditions are determined by voltages and currents in the circuit [1]. By using diode, the DC level of the output and the power transferred to the load are fixed when the source and load parameters are established. It produces an output waveform that is half of the incoming AC voltage waveform.

The positive pulse output waveform occurs because of the forward-biased condition of the diode. A diode experiences a forward-biased condition when its anode is at a higher potential than its cathode. Reverse bias occurs when its anode is lower than its cathode. During the positive portion of the input waveform, the diode becomes forward biased, which allows current to pass through the diode from anode to cathode, such that it flows through the load to produce a positive output pulse waveform. Over the negative portion of the input waveform, the diode is reverse-biased ideally so no current flows. Thus, the output waveform is zero or nearly zero during this portion of the input waveform.

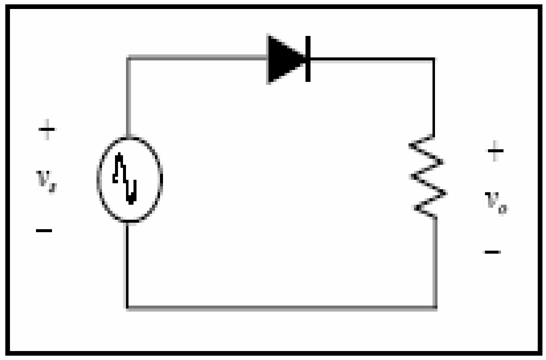

Figure 2.1 Single Phase Half-Wave Rectifier

2.2.2 Single Phase Full-Wave Rectifiers

The purpose of the full-wave rectifier is basically the same as that of the half-wave rectifier but full-wave rectifiers have some fundamental advantages. There are two types of full-wave rectifiers that are the bridge rectifier and the center-tapped rectifier as shown in Figure 2.2 and Figure 2.3.

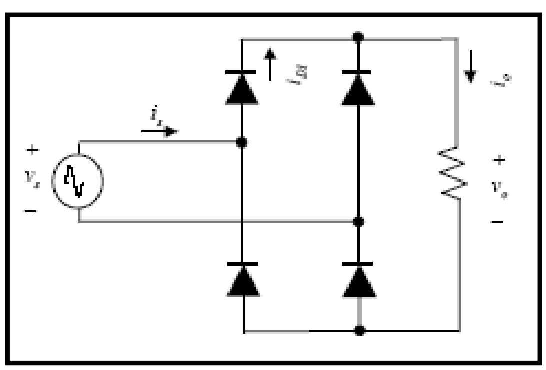

Figure 2.2 The Bridge Rectifier

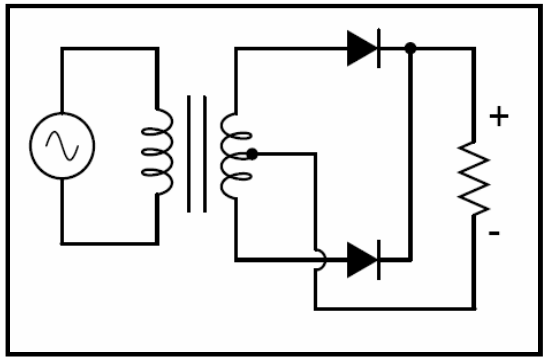

Figure 2.3 The Center-Tapped Transformer Rectifier

The lower peak diode voltage in the bridge rectifier which consists of four diodes arranged makes it more suitable for high-voltage applications. Thus, the center-tapped transformer rectifier in addition to including electrical isolation has only one diode voltage drop between the source and load making it desirable for low-voltage and high current applications.

2.3 Controlled Single Phase Rectifier

The previous rectifiers are classified as uncontrolled rectifiers but once the source and the load parameters are established, the DC level of the output and the power transferred to the load are fixed quantities. As mentioned before that the output voltage of the AC-DC converters using diodes is not controllable because the diodes are not self-controlled switch [10]. Thus, there is a way to control the output by using thyristor instead of a diode. A thyristor is a four-layer (*pnpn*), three-junction device that conducts current only in one direction similar to a diode.

2.3.1 Single Phase Half-Wave Rectifiers

Unlike the diode, the silicon controlled rectifier (SCR) will not to begin to conduct as soon as the source becomes positive [1]. Gate trigger current is the minimum current required to switch silicon controlled rectifiers from the off-state to the on-state at the specified off-state voltage and temperature. Once the SCR is conducting, the gate current can be removed and the SCR remains on until the current goes to zero [1]. Figure 2.4 shows a basic controlled half-wave rectifier.

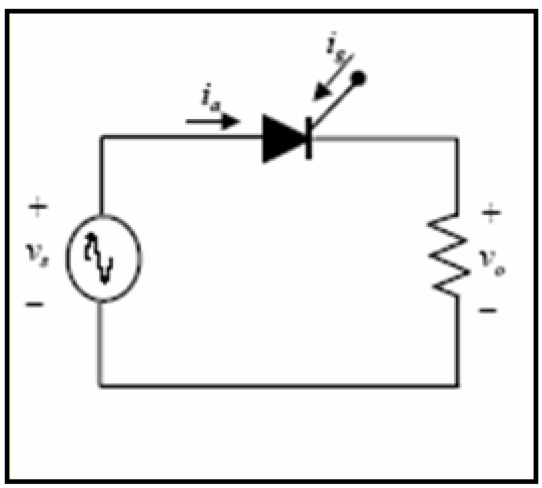

Figure 2.4 A Basic Half-Wave Controlled Rectifier

2.3.2 Single Phase Full-Wave Rectifiers

Popular AC-DC converters use full-bridge topologies [10]. Full-bridge converters are designed for delivering constant but controllable DC current or DC voltage to the load. Similar to the diode bridge rectifier topology, a versatile method of controlling the output of a full-wave rectifier is to substitute controlled switches such as SCRs for the diode. Because of their unique ability to be controlled, the output voltage and hence the power can be controlled to desire levels. The triggering of the thyristor has to be synchronized with the input sinusoidal voltage in an AC to DC rectifier circuit. The delay angle α is the angle interval between the forward biasing of the SCR and the gate signal application [1]. Otherwise, if the delay angle is zero, the rectifiers behave exactly like uncontrolled rectifiers with diodes. Figure 2.5 shows a basic controlled full-wave rectifier.

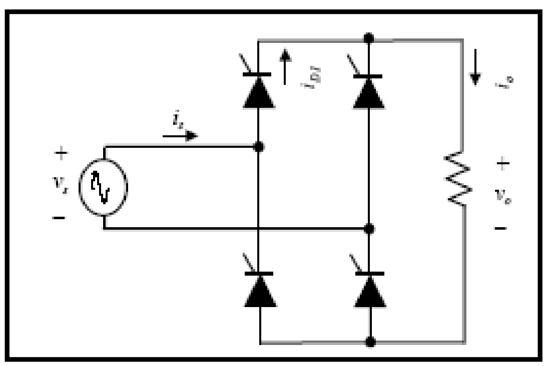

Figure 2.5 A Basic Full-Wave Controlled Bridge Rectifier

2.3.3 Phase Angle Delay Control

Converter operation in steady-state is best described over a period that begins from the phase α to 2π+ α [10]. This operation involves two circuit modes during a single period of the source waveform depending upon the state of the switches as shown in Figure 2.7. Mode 1 starts when the SCRs T1 and T3 are turned on at an angle α by control pulses applied at their gate terminals. During mode 1, SCRs T1 and T3 are in forward-biased mode and SCRs T2 and T4 are in reverse blocking mode. The current Io flows through the path shown in Figure 2.6. After angle π, the input source voltage become negative but the SCRs T1 and T3 still conducting. Note that the current sink is the model of a high value inductor, voltage across it can change instantaneously but current cannot [10]. Hence, the output voltage,Vo become negative and follows the input voltage,V_s waveform. The input source is supplying power to the load during α to π which is referred also as the rectifier operation.

Mode 2 begins when the SCRs T2 and T4 are turned on at an angle α + π by the control pulses applied at their terminals. The current is steered away from the SCRs T1 and T3 to T2 and T4 effecting a natural commutation. Now thyristors T1 and T3 are in reverse blocking mode [10]. This converter operation in this mode is identical to that mode 1 during the angle from π+α to 2π+α.

There several possible output voltages are shown in Figure 2.8 given duty ratio of 50%. The phase delay angle allows control over the DC output just as duty ratio control permits adjustment of the output in DC-DC converter [9]. Since DC output is of interest and because the output current comes along with a DC source, the average voltage Vo needs to be determined. Its value will be:

$$V_o = \frac{1}{\pi}\int_{\alpha}^{\alpha+\pi} V_m \sin(\omega t)\, d\omega t = \frac{2V_m}{\pi}\cos\alpha$$

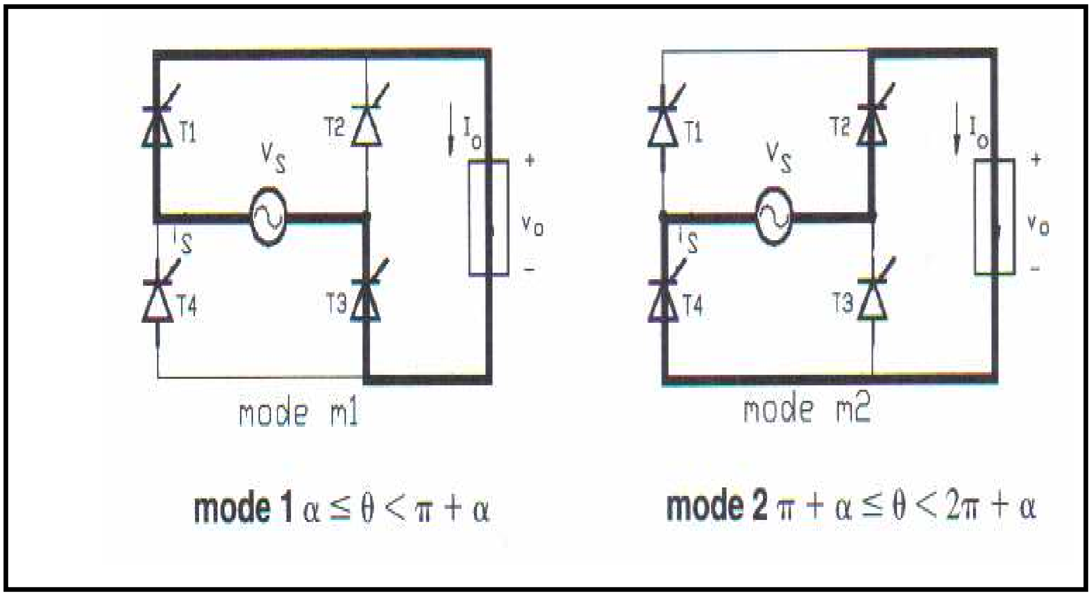

Figure 2.6 Circuit Modes

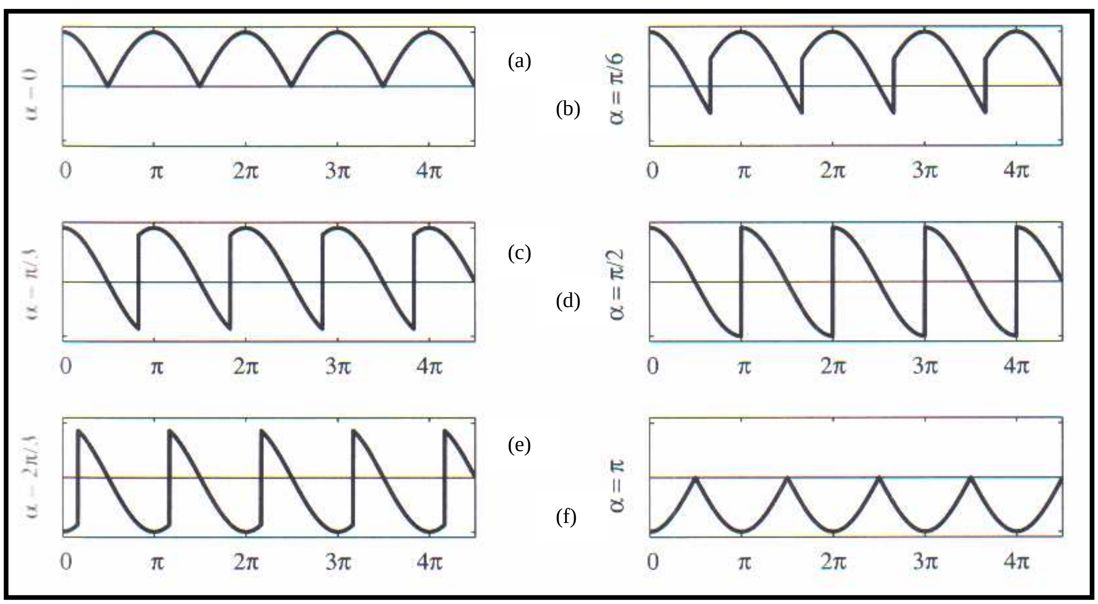

Figure 2.7 Possible Output Voltage waveform For SCR Bridge

2.4 Three Phase Rectifiers

Three phase rectifiers are more commonly used because of the following reasons: [8]

i. Three phase AC power is readily available.
ii. It is economical to provide DC supply to DC motors of capacity 20kW and more from a three phase rectifier rather than single phase.
iii. The ripple frequency of the output current of the three phase rectifiers is higher than that for single phase ones.

2.4.1 Three Phase Uncontrolled Rectifiers

Three phase rectifiers are commonly used in industry to produce a DC voltage and current for large loads [1]. Like single phase rectifiers, three phase rectifiers also have two types that are uncontrolled and controlled. The three phase full-bridge uncontrolled rectifier is shown in Figure 2.8. As mention before in single phase uncontrolled rectifier, this three phase full-bridge rectifier is using diodes as switch. Three phase rectifier divides into two groups which are top group and bottom group. For top group, diode with its anode at the highest potential will conduct at one time. The other two will be reversed. Thus for bottom group, diode with the its cathode at the lowest potential will conduct. The other two will be reversed. Figure 2.10 shows the phase voltage and the resulting combinations of line-to-line voltages from a balanced three phase source.

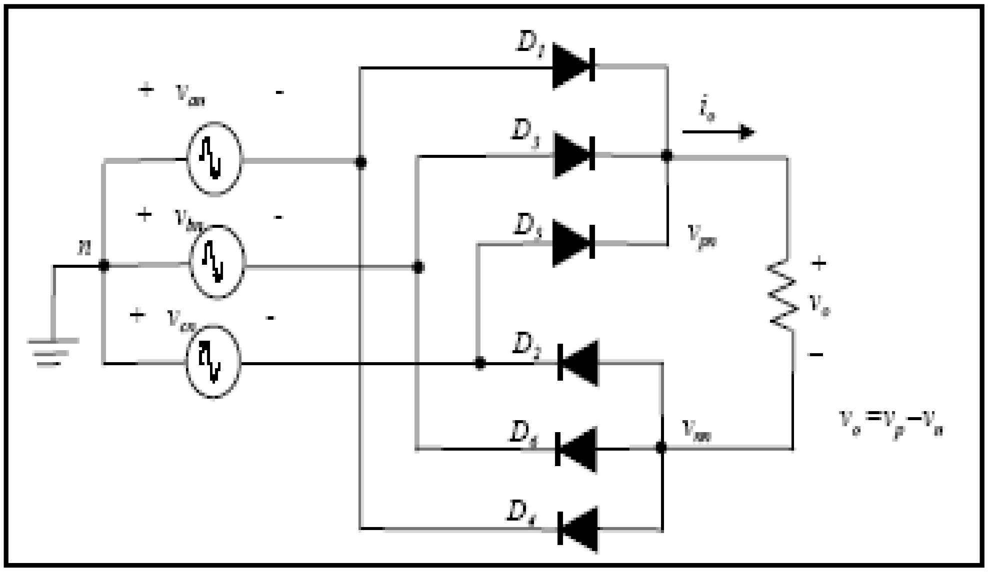

Figure 2.8 The Three Phase Full-Bridge Uncontrolled Rectifier

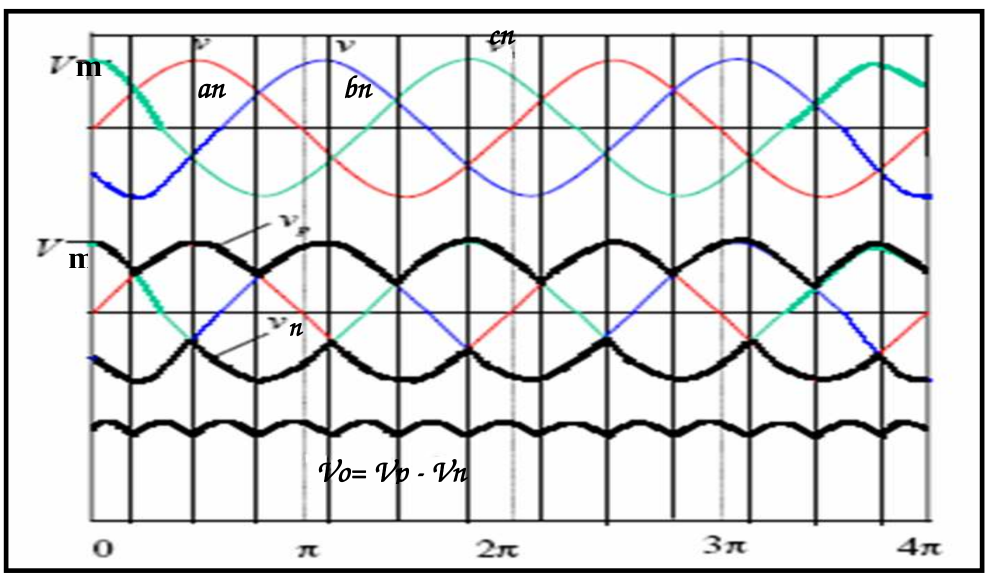

Figure 2.9 Source And Output Voltage

2.4.2 Three phase Controlled Rectifiers

Similar to single phase controlled rectifier, the output of the three phase rectifier can be controlled by substituting SCRs for diodes. Figure 2.10 shows a controlled six-pulse three phase rectifier. As mention before in single phase controlled rectifier, SCRs will conduct until a gate signal is applied while the SCR is forward biased. Thus, the transition of the output voltage to the maximum instantaneous line-to-line source voltage can be delayed [1].

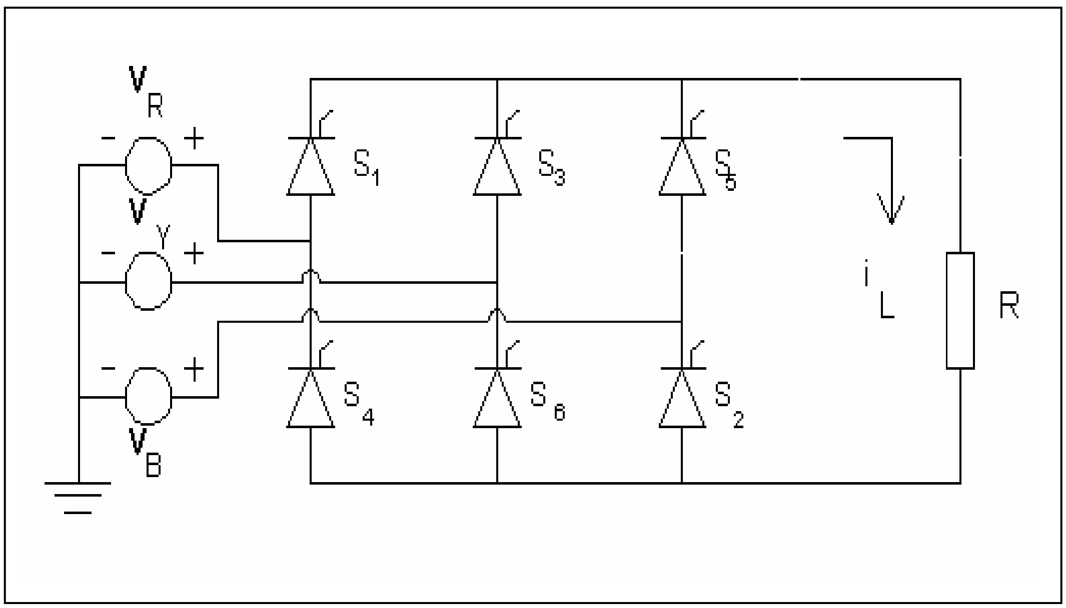

Figure 2.10 The Three Phase Full-Bridge Controlled Rectifier

2.5 Types of Thyristor

2.5.1 Silicon Controlled Rectifier

The thyristor is a solid-state semiconductor device with four layers of alternating N and P-type material. They act as a switch, conducting when their gate receives a current pulse, and continue to conduct for as long as they are forward biased (that is, as long as the voltage across the device has not reversed).

Some sources define silicon controlled rectifiers and thyristors as synonymous; others define SCRs as a subset of thyristors, along with gate turn-off thyristor (GTO), triode ac switch (triac), static induction transistor (SIT), static induction thyristor (SITH) and MOS-controlled thyristor (MCT). Among the latter, the International Electro technical Commission 60747-6 standard stands out.
Non-SCR thyristors include devices with more than four layers, such as triacs and DB-GTOs.

Function

The thyristor is a four-layer semiconducting device, with each layer consisting of alternately N-type or P-type material, for example P-N-P-N. The main terminals, labeled anode and cathode, are across the full four layers, and the control terminal, called the gate, is attached to p-type material near to the cathode. (A variant called an SCS Silicon Controlled Switch brings all four layers out to terminals.) The operation of a thyristor can be understood in terms of a pair of tightly coupled Bipolar Junction Transistors, arranged to cause the self-latching action:

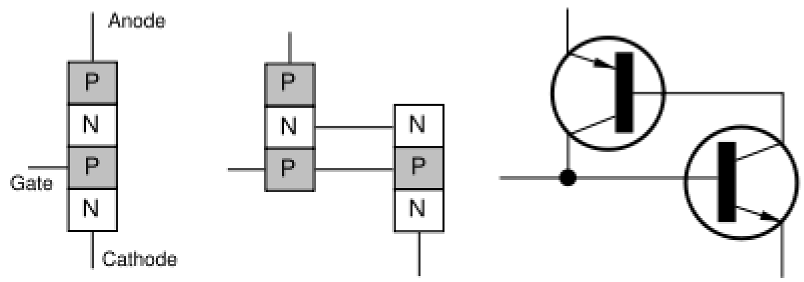

Figure 2.11 Thyristor

Thyristors have three states:

Reverse blocking mode -- Voltage is applied in the direction that would be blocked by a diode

Forward blocking mode -- Voltage is applied in the direction that would cause a diode to conduct, but the thyristor has not yet been triggered into conduction

Forward conducting mode -- The thyristor has been triggered into conduction and will remain conducting until the forward current drops below a threshold value known as the "holding current"

Function of the gate terminal

The thyristor has three p-n junctions (serially named J1, J2, J3 from the anode).

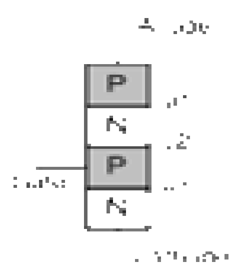

Figure 2.12 Layer Diagram of Thyristor

When the anode is at a positive potential VAK with respect to the cathode with no voltage applied at the gate, junctions J1 and J3 are forward biased, while junction J2 is reverse biased. As J2 is reverse biased, no conduction takes place (Off state). Now if VAK is increased beyond the breakdown voltage VBO of the thyristor, avalanche breakdown of J2 takes place and the thyristor starts conducting (On state).

If a positive potential VG is applied at the gate terminal with respect to the cathode, the breakdown of the junction J2 occurs at a lower value of VAK. By selecting an appropriate value of VG, the thyristor can be switched into the on state immediately.It should be noted that once avalanche breakdown has occurred, the thyristor continues to conduct, irrespective of the gate voltage, until either: (a) the potential VG is removed or (b) the current through the device (anode−cathode) is less than the holding current specified by the manufacturer. Hence VG can be a voltage pulse, such as the voltage output from a UJT relaxation oscillator.

These gate pulses are characterized in terms of gate trigger voltage (VGT) and gate trigger current (IGT). Gate trigger current varies inversely with gate pulse width in such a way that it is evident that there is a minimum gate charge required to trigger the thyristor.

Switching characteristics

In a conventional thyristor, once it has been switched on by the gate terminal, the device remains latched in the on-state (i.e. does not need a continuous supply of gate current to conduct), providing the anode current has exceeded the latching current (IL). As long as the anode remains positively biased, it cannot be switched off until the anode current falls below the holding current (IH).

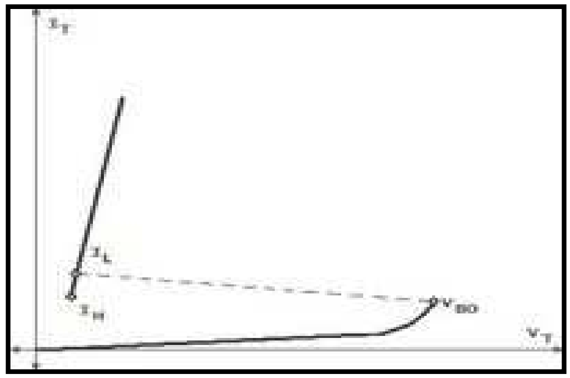

Figure 2.13 V - I Characteristics

A thyristor can be switched off if the external circuit causes the anode to become negatively biased. In some applications this is done by switching a second thyristor to discharge a capacitor into the cathode of the first thyristor. This method is called forced commutation.

After a thyristor has been switched off by forced commutation, a finite time delay must have elapsed before the anode can be positively biased in the off-state. This minimum delay is called the circuit commutated turn off time (tQ). Attempting to positively bias the anode within this time causes the thyristor to be self-triggered by the remaining charge carriers (holes and electrons) that have not yet recombined.

For applications with frequencies higher than the domestic AC mains supply (e.g. 50 Hz or 60 Hz), thyristors with lower values of tQ are required. Such fast thyristors are made by diffusing into the silicon heavy metals ions such as gold or platinum which act as charge combination centers. Alternatively, fast thyristors may be made by neutron irradiation of the silicon.

History

1956 The Silicon Controlled Rectifier (SCR) or Thyristor proposed by William Shockley in 1950 and championed by Moll and others at Bell Labs was developed first by power engineers at General Electric (G.E.) led by Gordon Hall and commercialized by G.E.'s Frank W. "Bill" Gutzwiller.

Application

Figure 2.14 A bank of six, 2000 A Thyristors (white pucks). The clear tubes are for cooling water

Thyristors are mainly used where high currents and voltages are involved, and are often used to control alternating currents, where the change of polarity of the current causes the device to automatically switch off; referred to as Zero Cross operation. The device can be said to operate synchronously as, once the device is open, it conducts current in phase with the voltage applied over its cathode to anode junction with no further gate modulation being required to replicate; the device is biased fully on. This is not to be confused with symmetrical operation, as the output is unidirectional, flowing only from cathode to anode, and so is asymmetrical in nature.Thyristors can be used as the control elements for phase angle triggered controllers, also known as phase fired controllers.

Thyristors can also be found in power supplies for digital circuits, where they can be used as a sort of "circuit breaker" or "crowbar" to prevent a failure in the power supply from damaging downstream components. The thyristor is used in conjunction with a zener diode attached to its gate, and when the output voltage of the supply rises above the zener voltage, the thyristor conducts, shorting the power supply output to ground (and in general blowing an upstream fuse).

The first large scale application of thyristors, with associated triggering diac, in consumer products related to stabilized power supplies within color television receivers in the early 1970s. The stabilized high voltage DC supply for the receiver was obtained by moving the switching point of the thyristor device up and down the falling slope of the positive going half of the AC supply input (if the rising slope was used the output voltage would always rise towards the peak input voltage when the device was triggered and thus defeat the aim of regulation).

The precise switching point was determined by the load on the output d.c. supply as well fluctuations on the input a.c. supply. They proved to be unpopular with the a.c. grid power supplier companies because the simultaneous switching of many television receivers, all at approximately the same time, introduced asymmetry into the supply waveform and, as a consequence injected d.c. back into the grid with a tendency towards saturation of transformer cores and overheating. Thyristors were largely phased out in this kind of application by the end of the decade.

Thyristors have been used for decades as lighting dimmers in television, motion pictures, and theater, where they replaced inferior technologies such as autotransformers and rheostats. They have also been used in photography as a critical part of flashes (strobes).